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THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

FEBRUARY, 1954

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Welding Rods and Electrodes Produced in U.S.A.

'Welding Rod and Electrode Charts.' *Iron Age*, 1953, vol. 172, Dec. 10, pp. 153-8.

The tables show types and trade names of welding rods and electrodes (for welding both steel and non-ferrous materials) made by twenty-three U.S. producers, together with the A.S.T.M./A.W.S. specifications to which the rods conform.

Glossary of Foundry Terms

See abstract on p. 27.

Marine Gas Turbines: Design, Materials, and Service Experience

See abstract on p. 30.

Carbon Dioxide Cooling in Machining of High-Temperature Alloys

See abstract on p. 32.

NICKEL

World Resources of Nickel

W. R. McCLELLAND: 'Nickel: An Expanding Canadian Industry.' *Canad. Mining Jnl.*, 1953, vol. 74, Dec., pp. 60–3.

This article describes the growth of the Canadian nickel industry (with graph indicating output from 1900 onwards), and briefly refers to some of the most recent major developments which are increasing production and improving quality. In this connexion, attention is directed to (1) the modification, by International Nickel Company of Canada, Ltd., of the Orford 'tops and bottoms' process, (2) the ammonia pressure leaching process developed by Sherritt Gordon Mines, Ltd. (for fuller details see *Nickel Bulletin*, 1953, vol. 26, Nos. 8–9, p. 127), and (3) production of iron ore as a by-product in nickel extraction, recently announced by International Nickel Company: see *Nickel Bulletin*, 1953, vol. 26, Nos. 8–9, p. 127.

A survey is also made of exploration and expansion programmes which are under way in Canada, sponsored by INCO, Falconbridge Nickel Mines, Sherritt Gordon Mines, and other companies.

The final section of the review comprises a brief survey of nickel resources and recent developments in countries other than Canada, including New Caledonia, Finland, Cuba, Greece, and the U.S.A.

Hydrometallurgy of Nickel and other Base Metals

G. D. VAN ARSDALE: 'Hydrometallurgy of Base Metals.' *Published by McGraw–Hill Book Co., Inc., New York*, 1953; 370 pp. Price 81/–.

This book deals with 'the theory and practice of recovering metals other than gold and silver from their ores or concentrates by dissolving them with some solvent and then preparing them in a pure state.' The basic processes usually involved in such cycles are discussed in chapters describing the general chemistry of roasting and leaching; crushing, grinding and classification methods, and procedures employed for leaching, separation of solutions, solution–purification, and recovery of metal. Later chapters give detailed information on operating data in plants engaged in extraction of nickel, manganese, tin, cadmium, vanadium, cobalt and iron. A summary is also made of published accounts of methods for treating uranium- and radium–containing materials. The section on nickel describes the plant and process of Nicaro Nickel Company, which, during the war, were used to treat the low–nickel lateritic iron ores of Cuba. The last two chapters are concerned with the history of hydrometallurgy and its future prospects.

Nickel Catalyst in Uranium-Extraction Process

F. A. FORWARD, *et al.*: 'Studies in the Carbonate Leaching of Uranium Ores. I. Description of the Pressure Leach Process and its Application to Pitchblende Ores. II. Kinetics of the Dissolution of Pitchblende. III. Precipitation of Uranium from Carbonate Solutions by Reduction with Hydrogen.' *Canad. Mining and Metallurgical Bull.*, 1953, vol. 46, Oct., pp. 634–48; *Trans. Canad. Inst. Mining and Metallurgy*, 1953, vol. 56, pp. 344–58.

The papers describe a new process for extracting uranium from pitchblende ores, developed at the Metallurgical Laboratories of the University of British Columbia. It involves leaching the ore with aqueous carbonate solutions in the presence of

gaseous oxygen, under pressure. The method can be used with particular advantage in treating low-grade ores, the carbonate content of which is too low to allow them to be treated economically by conventional acid-leaching procedures.

In the precipitation process described in the last of the three papers a nickel catalyst, in powder or gauze form, has proved highly efficient and economical.

Nickel-containing Catalysts in Processing Grape-Seed Oils

R. RIGAMONTI: 'Investigations on Grape-Seed Oils: Experiments on Isomerizing the Double Bonds.' *Olearia*, 1952, vol. 6, pp. 139–43; *Chemical Abstracts*, 1953, vol. 47, Oct. 25, p. 10,872.

Report of investigations resulting in development of oils having improved drying properties. Of various catalysts used in the experiments, the best proved to be nickel–cobalt on active carbon, followed by Raney nickel, and nickel on active carbon. For fuller details see *Chemical Abstracts*, *loc. cit.*

Nickel Catalysts in the Synthesis of Methane

DEPT. SCIENTIFIC AND INDUSTRIAL RESEARCH: 'Catalytic Enrichment of Industrial Gases by the Synthesis of Methane.' *Fuel Research Tech. Paper No.* 57, 1953; 51 pp.

It has long been recognized that the catalytic synthesis of methane from carbon monoxide and hydrogen in water gas and other industrial gases is a possible process for the enrichment of such gases to the calorific value of town's gas. The work described in this report was carried out with the object of developing a process suitable for operation on a large scale. Details are given of a laboratory-scale investigation, followed by tests with intermediate-scale plant. Resulting from these tests, recommendations have been made for methods of construction of full-scale plant to process 20,000 cu. ft. of water gas per hour. A nickel–base catalyst is used.

Temperature Dependence of Magnetostriction in Nickel

A. Y. VLASOV: 'Investigation of the Temperature Dependence of Magnetostriction in Nickel by the Method of Automatic Photo-Recording.' *Izvest. Akad. Nauk, S.S.S.R., Ser. Fiz.*, 1952, vol. 16, pp. 718–23; *Chemical Abstracts*, 1953, vol. 47, Oct. 25, p. 10,294.

The main features of the apparatus used are given in the abstract. Saturation magnetostriction of nickel was found to be a linear function of temperature.

Ferromagnetism of Thin Films of Nickel

H. H. JENSEN and A. NIELSEN: 'Ferromagnetism of Thin Nickel Films.' *Trans. Danish Acad. Tech. Sciences*, 1953, No. 2, pp. 3–14.

The saturation magnetic polarization of nickel films 8–500 Å in thickness, evaporated on glass, was measured. It was found to decrease rapidly at a thickness of about 100 Å, and to vanish at thicknesses below 16 ± 4 Å. The authors describe an absolute method of determining the film thickness by means of magnetic measurements: the results are compared with those obtained by weighing.

Anodic Oxidation of Nickel at Low Current Density

S. E. S. EL WAKKAD and S. H. EMARA: 'The Anodic Oxidation of Metals at Very Low Current Density. Part II. Nickel.' *Jnl. Chemical Soc.*, 1953, Nov., pp. 3504–8.

The conflicting results of various workers on the variation of the anode potential with the quantity of electricity passed when a nickel electrode is forced from evolution of hydrogen to that of oxygen, as well as on the type of oxides formed on the surface of the metal before oxygen evolution, have been clarified by carrying out anodic oxidation of nickel in solutions of different pH values at very low current density. It is shown that the oxides formed on the anode before evolution of oxygen depend on the polarizing current: at extremely low current density the oxides NiO, Ni_3O_4, Ni_2O_3, and NiO_2 are formed before oxygen is evolved, but at higher current density only the oxides NiO, Ni_2O_3 and NiO_2 appear. The primary anodic products are, however, the oxides NiO and NiO_2; Ni_3O_4 and Ni_2O_3 are formed from a secondary reaction between NiO and NiO_2. The higher oxides are unstable, decomposing to NiO, the most stable oxide in contact with the metal.

Iron, Cobalt and Nickel Sulphides: a Thermodynamic Investigation

T. ROSENQUIST: 'A Thermodynamic Study of the Iron, Cobalt and Nickel Sulphides.' *Jnl. Iron and Steel Inst.*, 1954, vol. 176, Jan., pp. 37–57.

The thermodynamics of the iron, cobalt and nickel sulphides were studied at temperatures of 400°–1200°C. by means of hydrogen/hydrogen-sulphide equilibria and measurements of sulphur pressure. The stability ranges of the different sulphide phases, and their free energies of formation, were determined.

In the iron–sulphur system the results indicate that FeS_2 has a peritectic decomposition point at about 800°C. and 25 atm. pressure.

In the cobalt–sulphur system the following phases were observed within the temperature ranges shown in brackets: $Co_4S_3 \pm x$ (780°–930°C.); Co_9S_8 (up to 835°C.); CoS_{1+x} (460°C.—m.p.); Co_3S_4 (up to 625°C.), and CoS_2.

In the nickel–sulphur system the following phases were observed: Ni_3S_2 (up to 555°C.); $Ni_3S_{2 \pm x}$ (525°–810°C.); Ni_6S_5 (up to 560°C.); NiS_{1+x}, and NiS_2.

The stability of the different sulphides decreases in the sequence iron sulphides to nickel sulphides. Simultaneously, the composition of the most stable sulphide shifts towards lower sulphur contents. The results are discussed, with emphasis on their connexion with the structure of the different phases and the nature of the interatomic binding forces.

Modern Uses of Non-Ferrous Metals

See abstract on p. 25.

ELECTRODEPOSITION AND OTHER COATING METHODS

Electrochemical Society Handbook on Electrodeposition

A. G. GRAY (Editor): 'Modern Electroplating.' *Published by John Wiley and Sons, Inc., New York*; *Chapman and Hall, Ltd., London*, 1953; Price 68/-.

This handbook, which is sponsored by The Electrochemical Society, supersedes the book of reference published under the same title in 1941 (reviews in *Nickel Bulletin*, 1941, vol. 14, Nos. 11-12, pp. 180-3 and vol. 15, Nos. 8-9, pp. 126-7). The earlier volume comprised a series of concise monographs on the current position of development in all fields of electrodeposition, written by specialists in the respective aspects of the subject. In planning the revised edition the same principle has been adopted, but the scope has been widened, and sections of the earlier edition which have been used as a basis have been re-written in the light of many important developments which have taken place since 1941. The subject matter may therefore be regarded as an authoritative review of present knowledge and current practice in the field of electroplating. The scope of the material contained in the handbook is indicated below. Each chapter deals comprehensively with composition and control of the solutions used in electrodepositing the respective metals, and in most cases full details are given of analytical control procedure, and of tests employed for evaluation of the quality of the electrodeposited coatings. In all cases the information given is supported by comprehensive *bibliographies*.

W. BLUM and W. R. MEYER: 'General Principles', pp. 1-46.

R. A. SCHAEFER, H. J. SEDUSKY and B. LUCE: 'Methods of Control', pp. 47-63.

C. L. FAUST: 'Alloy Plating', pp. 64-97.

L. E. WEEG and H. J. WIENER: 'Brass', pp. 98-115.

K. G. SODERBERG and L. R. WESTBROOK: 'Cadmium', pp. 116-34.

'Chromium', pp. 135-87.

(1) G. DUBPERNELL: 'The Chromium Plating Process', pp. 135-77.

(2) C. A. SNAVELY and C. L. FAUST: 'Properties of Chromium Plate', pp. 177-87.

H. B. LINFORD: 'Cobalt', pp. 188-93.

'Copper', pp. 194-251.

(1) A. K. GRAHAM and H. J. READ: 'Rochelle Copper', pp. 194-213.

(2) R. R. BAIR and D. A. SWALHEIM: 'High-Efficiency Cyanide Copper', pp. 213-25.

(3) J. E. STARECK: 'Pyrophosphate Copper', pp. 225-31.

(4) W. H. SAFRANEK and J. H. WINKLER: 'Acid Copper Electroplating and Electroforming', pp. 231-51.

L. WEISBERG and A. K. GRAHAM: 'Gold', pp. 252-66.

H. B. LINFORD: 'Indium', pp. 267-70.

C. T. THOMAS and V. A. LAMB: 'Iron', pp. 271-81.

A. H. DU ROSE and W. BLUM: 'Lead', pp. 282-98.

W. L. PINNER, K. G. SODERBERG and W. A. WESLEY: 'Nickel', pp. 299-355.

This review, supported by a *bibliography* of 172 references, opens with a brief historical survey of development of the nickel-plating process, and with a summary of specifications jointly sponsored by the American Society for Testing Materials and the American Electroplaters' Society.

The coverage provided by this very comprehensive chapter is indicated by the following list of aspects with which the authors deal in considerable detail:—

Selection of electrolytes for decorative plating: principles of nickel plating; the Watts' bath (the function of its constituents and the effects of controllable variables); bright nickel baths of various types (composition, characteristics and operation); semi-bright nickel plating; special-purpose baths (electrotyping baths, the double-salt bath, barrel-plating solutions, high-sulphate baths and black-nickel baths); maintenance and control of nickel-plating solutions (effect of various types of contaminant and methods for their removal; analytical methods for determination of the main constituents of the baths); anodes (improvements in purity during the past 40 years, rolled-depolarized, carbon-nickel, and electrolytic types); preparation of basis metals for nickel plating (polishing and buffing, electropolishing, cleaning and pickling); finishing of nickel deposits; tests and specifications. Heavy nickel plating is considered in a separate section of the review, which gives details of the baths used, of the properties obtainable in soft and hard heavy-nickel deposits, and of the use of such deposits in reinforcement and salvage of engineering parts and in electroforming. Stress in nickel deposits is also considered, with a summary of publications on the theory of the problem, the effect of bath variables on the stress present in deposits, and the relation of internal stress and ductility.

K. SCHUMPELT: 'Platinum Group Metals', pp. 356-66.

N. E. PROMISEL: 'Silver', pp. 367-86.

'Tin', pp. 387-442.

(1) F. BAUCH and F. F. OPLINGER: 'Stannate Tin', pp. 389-410.

(2) P. R. PINE and A. H. DU ROSE: 'Acid Tin', pp. 410-28.

(3) F. A. LOWENHEIM: 'Immersion Tinning', pp. 429-42.

'Zinc', pp. 443-82.

(1) E. H. LYONS and H. P. MUNGER: 'Acid Zinc', pp. 444-59.

(2) R. R. BAIR and L. J. SCHUSTIK: 'Cyanide Zinc', pp. 460-82.

F. A. LOWENHEIM: 'Uncommon Metals', pp. 483-510.

A well-documented review of work which has been published on electrodeposition of the following elements: actinium, aluminium, antimony, arsenic, beryllium, bismuth, calcium, cerium, gallium, germanium, hafnium, lanthanum, magnesium, manganese, mercury, molybdenum, niobium, polonium, proactinium, rare-earth metals, rhenium, selenium, tantalum, tellurium, thallium, thorium, titanium, tungsten, uranium, vanadium, zirconium.

F. KELLER: 'Plating on Aluminum Alloys', pp. 511–24.
H. K. DELONG: 'Plating on Magnesium Alloys', pp. 524–35.

The final section of the handbook contains tables of useful data and miscellaneous information for use by electroplaters.

Metallographic Study of Steels Used for Nickel Plating

A. E. R. WESTMAN and F. A. MOHRNHEIM: 'A Metallographic Study of Some Steels used for Nickel Plating.' *Plating*, 1953, vol. 40, Dec., pp. 1366–73; disc., pp. 1373–5.

Full form of paper abstracted in *Nickel Bulletin*, 1953, vol. 26, Nos. 8–9, p. 132.

Research Project No. 14 operated by the American Electroplaters' Society covers the 'influence of the physical metallurgy and mechanical properties of the basis metal on electroplating'. It is therefore concerned with any factor which may influence the qualities of a plated article by affecting the properties of the metal onto which it is electrodeposited. Initially the investigations are being confined to steel as the basis material, with nickel, nickel+chromium, or copper+nickel+chromium as the coatings.

Review of the literature showed that opinions differ widely on the subject of the influence of surface finish of the base metal: some writers maintain that the properties of an electrodeposit are unaffected by wide variations in the polishing procedure, whereas others consider that any polishing operation leaves a disturbed metal surface which provides an insecure basis for electroplating.

The section of work by A.E.S. Project 14 which is reported in this paper was undertaken with the aim of (1) finding the range of steels currently being used for plating; (2) perfecting known techniques for studying the zone of contact between the basis metal and the coatings; and (3) studying some plating failures in which the basis metal might be at fault.

(1) is considered in relation to the chemical composition, ingot practice (killed, semi-killed, capped or rimmed steels), and rolling practice normally used for steels which are to be plated. Most of the specimens examined were of the S.A.E.1010 (carbon 0·08–0·13 per cent.) type. Under (2) techniques examined were (*a*) ordinary metallographic examination, and (*b*) the use of taper sectioning, the latter method being used particularly for the study of the disturbed layer at the junction of the basis metal and the electroplate. The principle of taper sectioning is diagrammatically illustrated, and photomicrographs of typical plated components are shown.

Among the specimens of plating failures examined were (1) a parking-light housing, in which the basis steel had been severely deformed; (2) an automobile bumper guard, on which corrosion blisters on exposed surfaces were found to be related to the position of polishing scratches on the basis metal; (3) a nickel-plated skate blade, in which defects in the plating were associated with cracks in the carburized basis steel, and (4) a chromium-plated steel cylinder, in which imperfections in the steel surface were clearly reflected in the coating.

Although only tentative conclusions can yet be drawn from the work done under this project, it is considered that the results already obtained demonstrate beyond dispute that the relation of basis-metal properties to the quality of the plating provides a fruitful field for further study.

Reactions between Organic Compounds and the Metal Surface during Electrodeposition of Nickel

C. C. ROTH and H. LEIDERHEISER: 'The Interaction of Organic Compounds with the Surface during the Electrodeposition of Nickel.' *Jnl. Electrochemical Soc.*, 1953, vol. 100, Dec., pp. 553–65.

Organic compounds, in small concentrations, are added to metal plating baths for a variety of purposes, e.g., to lessen pitting, to increase hardness, to reduce strains in the deposit, to add brightness to the coating. Baths of this type which are now successfully used in electrodeposition of nickel and other metals have, in some cases, been developed on a somewhat empirical basis and to date relatively few reports on the scientific study of the subject have been published.

In an attempt to fill the gap, the present authors have carried out cathode–potential measurements during electrodeposition of nickel from baths containing, individually, 76 organic compounds, of which details are given.

The solution used was of the Watts type ($NiSO_4.6H_2O$, 240 g./L; $NiCl_2.6H_2O$, 45 g./L; H_3BO_3, 30 g./L.). All tests were made with the pH of the bath adjusted to 4·0. The cathode was mechanically polished through 4 to 0 emery paper prior to each run and was then preplated with nickel for 10 minutes from a bath containing no organic addition, at 2 amp./dm². The following experimental conditions were standard in the majority of the tests with baths containing addition media; temperature 30°C.; current density 1 amp./dm²; pH 4·0; agitation, none. A few supplementary experiments were carried through at 50°C., using a current density of 2·0 amp./dm².

The following summary is made of the conclusions drawn from the tests: 'Ability of the compounds to make the cathode potential more negative, at a fixed current density, was found to be dependent on: (*a*) the acidic or basic character of the compound; (*b*) the size of the molecule; and (*c*) the number of available pairs of electrons in the molecule. Available pairs of electrons are defined as those which are capable of being shared with other atoms through association or chemical reaction without breaking completely the original bond between the atoms involved. Cathode polarization was appreciably increased by low concentrations of basic compounds with a large number of available pairs of electrons and/or with a large molecular size. The comparative effectiveness of chemical groups in increasing polarization decreased in the following order: nitrogen in conjugated bicyclic ring, nitrogen in conjugated monocyclic ring, nitrile, aldehyde, amino, nitro, tertiary amine, sulphone, sulphonylamide, sulphonate, carboxyl, ketone, and phenolic or alcoholic

hydroxy. Simultaneous measurements of cathode potential and brightness of the surface indicated that the largest compounds required the smallest concentration to brighten the surface, and the smallest compounds required the largest concentration. Brightening first occurred in the majority of instances at a cathode potential 20–50 mv. more negative than that of an unadulterated bath. The conclusion was drawn that the lowest concentration required for brightening corresponded to a specific fractional coverage of the surface. Brittleness, peeling, and cracking of the deposit were correlated with high polarizations. The origin of the change of the cathode potential in the presence of organic compounds was attributed to interference at the cathode surface with some stage in the overall process $Ni^{++}+2e \rightarrow Ni$(cryst.). Adsorption experiments with Raney nickel, and measurements of the electrode potential in 1*N* hydrochloric acid indicated that the compounds most effective in increasing the cathode potential were readily adsorbed by nickel. The experiments in hydrochloric acid also indicated that the adsorbed compounds interfered with the electron transfer, and X-ray measurements, reported in another paper, showed that the compounds interfered with crystal growth.

Effect of Chromium in Nickel-Plating Solutions

D. T. EWING, *et al.*: 'Effect of Impurities and Purification of Electroplating Solutions. I. Nickel Solutions. 7. The Effects and Removal of Chromium.' *Plating*, 1953, vol. 40, Dec., pp. 1391–400; disc., p. 1400.

Full form of paper presented at 1953 Annual Meeting of the American Electroplaters' Society; briefly referred to, from abstract source, in *Nickel Bulletin*, 1953, vol. 26, Nos. 8–9, p. 132.

This paper, reporting research carried out under A.E.S. Research Project 5, records investigation of the effect of hexavalent chromium, Cr (VI), and/or trivalent chromium, Cr (III), on the appearance, adhesion, ductility, salt-spray-fog corrosion-resistance, and hardness of nickel electrodeposits, and on the throwing power of the solutions. Watts' baths of high and low pH, nickel-cobalt, and organic baths were used. Full details are given of the experimental conditions and the results of the individual series of tests. The observations made lead to the following conclusions:

'The concentration of trivalent chromium affected the maximum amount of hexavalent chromium that could be present and *vice-versa*: the more trivalent chromium in solution, the lower the concentration of hexavalent chromium must be, the converse also being true. When both were present, their combined effect was greater than when either was present alone.

'The effect, on appearance, of chromium in either the hexavalent or trivalent state was not pronounced. In a Watts' pH 2·2 solution the presence of trivalent chromium in excess of 25 mg./L. produced a smoother, finer-grained deposit. When hexavalent chromium was present in concentrations varying from 15 to 75 mg./L. the deposits were whiter, but not noticeably smoother or finer grained. Trivalent chromium started to precipitate in the Watts' pH 5·2 solution almost immediately when trivalent or hexavalent chromium was the initial impurity. Roughness appeared in both cases. The hexavalent chromium produced a whiter deposit than a pure solution, an effect not noticed when trivalent chromium only was present. Chromium in both valence states produced stress in the nickel-cobalt deposits but otherwise had no effect. Its effect on deposits from the organic nickel solution was to cause a slight milkiness when present in the trivalent state in sufficient concentration (125 mg./L. or more). Hexavalent chromium had little effect on the deposits from the organic-type solution containing up to 20 mg./L.

'No discernible change in the adhesion of the deposits to the base metal was noted in the specimens from any of the solutions containing either hexavalent or trivalent chromium, within the concentration ranges studied, as long as careful control of conditions during deposition was maintained.

'The ductility of the deposits from all four types of solutions was noticeably decreased when trivalent or hexavalent chromium was present in solution. The decrease was, in general, more pronounced when hexavalent chromium was the impurity than when trivalent chromium was the sole contaminant.

'With the exception of the Watts' pH 5·2 deposits, the addition of chromium in either the hexavalent or the trivalent form resulted in a lowering of the hardness. The nickel-cobalt series with chromium (III) showed both an increase and a decrease in hardness. Ability of the chromium to increase hardness seems to be a function of pH of the solution.

'In general, the salt-spray corrosion-resistance of the deposits from the four types of solution decreased as the trivalent chromium content increased. The maximum decrease was of the order of 25 per cent. Hexavalent chromium seemed to have little effect on this property. Its effect was to increase corrosion-resistance in some cases, i.e., Watts' pH 2·2, and decrease it slightly in others, i.e., organic and nickel-cobalt. The deposits from the Watts' pH 5·2 solution showed both an increase and decrease in this property. The hexavalent chromium appeared to override the effect of trivalent chromium to reduce corrosion-resistance. The concentration of trivalent chromium had an effect here also. The higher the concentration of trivalent chromium in the presence of hexavalent chromium, the lower was the salt-spray resistance.

'The efficiency of the solutions was unimpaired by the presence of trivalent and/or hexavalent chromium. The effect of the trivalent chromium was to increase slightly the throwing power of the two Watts'-type solutions and the organic-type solution. A slight decrease in this property was noted with the nickel-cobalt-type solution. Hexavalent chromium increased the throwing power of the organic and Watts' pH 5·2 solutions and decreased the throwing power of the nickel-cobalt and Watts' pH 2·2 solutions.'

With regard to means for reduction or removal of chromium, the authors make the following recommendations:—

'The concentration of chromium may be reduced to

5 mg./L. or less by high-pH precipitation, using nickel carbonate. Maintaining the solution at a temperature of 75°C. or higher appreciably increases the rate of removal, and allowing the solution to stand at room temperature for several hours after heating makes the removal more complete. This method is satisfactory for hexavalent chromium if the chromium (VI) is first reduced to the trivalent state by electrolytic or chemical means. For the latter, nickel metal in a solution of low pH, with agitation, works well.

'Electrolytic removal of chromium at current densities below 40 amp./sq. ft., either from the hexavalent state or the trivalent state, is unsatisfactory. The trivalent chromium is removed very slowly if at all, and the hexavalent chromium, although it is deposited at high current densities, is reduced to the trivalent state faster than it is removed.'

Analysis of Electroplating Solutions

E. J. SERFASS, *et al.*: 'The Analysis of Electroplating Solutions for Major Constituents.' *Plating*, 1953, vol. 40, Dec., pp. 1383–9; disc., pp. 1389–90.

This paper, issued under the aegis of A.E.S. Research Project 2, surveys the programmes drawn up by the Committee responsible for prosecution of research on analysis of plating solutions, and summarizes the work done to date, which has covered methods for determination of 27 elements in copper-, nickel-, and zinc-plating baths, and the development (in co-operation with the Ohio River Valley Water Sanitation Commission) of 18 specialized analytical procedures for estimation of trace constituents in wastes from electroplating or metal-finishing solutions. Some reports on the first part of this project have been published from time to time in *Plating* (and, where appropriate, referred to in *The Nickel Bulletin* at the times of publication). The final report on the second aspect will be issued by the Ohio River Valley Water Sanitation Committee and published at intervals in *Plating*.

The A.E.S. Research Committee has now under consideration the assembly of all the analytical data which has been built up by Project 2, in the form of a 'Handbook of Solution Control for Platers'.

The current major commitment of this Committee is the investigation of macro-analytical methods for determination of the major constituents of plating baths. In this paper, the authors outline the factors which they consider to be important in this research, and summarize briefly the principal conclusions which they have reached as a result of testing of macro methods already available to the plater for analysis of nickel- and copper-plating baths. They also describe, in detail, two new specialized methods of analysis which have been developed under this Project, for (*a*) determination of boric acid, and (*b*) determination of alkali hydroxide in cyanide plating baths.

Nickel-Chromium-Coated Steel 'Cards'

'Speciality Steel Developed for Dialling System.' *Steel*, 1953, vol. 133, Dec. 14, p. 108.

An important item in the Bell Telephone Laboratories long-distance dialling system is a type of card file by which dial systems can be read. On arrival of a call the cards are lifted by magnets, exposing the one required, and the pattern of perforations on this card is projected by beams of light on to a bank of transistors which operates switches to set up the best connexion. In the early stages of this development it was found that there was no steel commercially available which would meet the combined requirements for strength, long life and swift magnetic reaction. To meet this need the Pittsburgh Steel Company has developed nickel+chromium-coated 'cards' of high-carbon steel, which, although so strong, are light; a load of 1,200 cards weighs less than 100 lb. The Company records that already this product is being widely used by many organizations for making into 'cards' for various purposes, and that consumption is likely to increase.

Electroless Plating: Industrial Experience

T. A. DICKINSON: 'Electroless Plating in Production.' *Sheet Metal Industries*, 1954, vol. 31, Jan., pp. 19–21, 30.

This article is based on developments in the plant of The Chemplate Company, of Los Angeles, which is now using, on a production scale, the electroless plating process developed from the researches of BRENNER and RIDDELL, at the National Bureau of Standards. For reference to an account of the current status of this process, see abstracts in *Nickel Bulletin*, 1953, vol. 26, Nos. 8–9 and 10, pp. 137 and 169.

Chemplate emphasize the importance of thorough cleaning as a major factor in ensuring success of plating by this process; the cycle recommended involves immersion in an emulsion cleaner, rinsing in cold water, removal of heavy oxides with a suitable acid solution, removal of grease with an alkaline cleaner, and removal of oxides with a final acid dip. The exact composition of the solution used in this plant is not disclosed, but it is stated to be 'functionally similar to the acid bath developed by Brenner and Riddell', of which details are given below:—

	oz./gall.
Nickel chloride	4
Sodium hypophosphite ..	1·3
Sodium hydroxyacetate ..	6·7
Brighteners	optional
pH 4–6	

Although no current is required for deposition, experience has shown that the basic cost of operation of the electroless process is slightly higher than that of electroplating, due to need for mechanical agitation of the solutions, the higher cost of pH-control equipment (by comparison with that needed for electrodeposition), and the requirement for special purification apparatus. These considerations lead the author of this article to the conclusion that 'electroless plating can now be regarded as economically practical only where related finishing methods are either wholly or partly unsatisfactory'. In this connexion it must be remembered that electroless plating makes possible the surface finishing of many products which could not otherwise be coated, due to the inadequate throwing power of electroplating solutions, e.g., both inner

and outer surfaces of tubing can be simultaneously nickel plated by the electroless procedure. In cases where extreme dimensional accuracy is essential a further advantage is the uniform thickness obtainable.

It is stated that standard qualitative tests have consistently shown that the adhesion of the deposits made by the Chemplate Company on brass and steel parts exceeds 50,000 p.s.i. (22·5 tons per sq. in.), a high value which is attributable to the fact that electroless plating establishes both chemical and mechanical bonds between the base and the coating. It is claimed that, due to the inherently lubricating properties characteristic of the coatings, the process has been used with particular success on gears, bearing surfaces and other components in which high-wear resistance is required.

Corrosion tests made on parts coated with nickel to a thickness of 0·001 in. are reported to have given the following results:

Salt spray: 200 hours minimum, without generalized rusting.

Outdoor exposure: six months minimum, without any rusting.

Hot-water immersion: six weeks in air-agitated water at 180°F., with no visible rusting.

In the as-plated condition the electroless nickel coatings are relatively brittle. Internal stresses may be relieved by heating the plated components to 750°F. (400°C.) for about 30 minutes, and where an increase in both mechanical strength and ductility is required short treatments at temperatures up to 1,100°F. (595°C.) may be used.

Due to the need for using the solutions at fairly high temperature, conventional masking materials cannot be used in selective plating by the electroless procedure, but satisfactory results can be obtained by using heat-resisting plastic strip.

As a considered opinion of the utility of the process at its present stage of development, the Chemplate organization believes it to be well suited for the coating of:—

(1) over-machined or over-tapped components,
(2) complex parts, such as valves, regulators and bearings, which have previously been impossible to plate,
(3) precision components such as instrument parts, fine gears, and threads,
(4) dies which have previously been chromium-plated and then ground,
(5) pipes, cylinders and tubing.

Accelerated Corrosion Testing of Electrodeposited Coatings

W. L. PINNER: 'Progress Report on Development of a New Accelerated Corrosion Test.' *Plating*, 1953, vol. 40, Dec., pp. 1376–8, 1383–4.

This report summarizes the current activities under A.E.S. Research Project 15, which was initiated in 1951 as a result of growing dissatisfaction with the validity of the salt-spray test as a method of evaluating the serviceability of decorative plated coatings: see *Nickel Bulletin*, 1952, vol. 25, Nos. 5 and 6, pp. 129 and 149. As a first step, the Committee responsible for this Project is sponsoring investigation of the design, fabrication, and exposure of plated parts; the gathering of pertinent data on conditions believed to contribute to the deterioration of plated coatings, and the carrying out of exploratory accelerated corrosion tests, in order to make qualitative selection of those which appear to have sufficient merit to justify quantitative study.

While most of the initial work is to be done on coatings deposited on steel, some plated diecastings are also to be included: the nature of the specimens which will thus be tested is described. Two types of plating on steel are to be studied in these tests: (1) straight nickel followed by chromium, and (2) a copper+nickel+chromium coating. The test panels will have varying total thicknesses. All coatings being used are selected as being representative of those now in widespread use in industry.

In connexion with the study of conditions producing deterioration in coatings, the Committee is arranging, in addition to the tests being carried out under its own auspices, to obtain, from various organizations, information on air-pollution conditions, use of de-icing compounds on streets (which could affect behaviour of car-licence brackets included in the tests), and the presence of other forms of contaminants in the atmospheres in which plated components normally work.

Experimental investigation of methods considered promising as a basis for development of improved accelerated corrosion tests is now in progress on the following lines:—

Salt-spray tests at temperatures lower than those normally used, i.e., approaching those encountered when roads are treated with salt during the winter months. These tests also include admission of corrosive gases such as sulphur dioxide, which change in solubility with temperature.

Continuous immersion in solutions made up to represent conditions which might be encountered in service.

Tests in solutions of appropriate composition, followed by exposure to humid atmosphere, with or without admission of corrosive gases, in a cycle of immersion and atmospheric exposure.

Cycles of chilling of specimens, followed by spraying with a solution simulating early rain containing dust in suspension.

Modified forms of the standard and acetic-acid-modified salt-spray test.

Addition, to the test environment, of solid particles (ash, dust, soot).

Use of a gelatin film as a reservoir of corrosive media, but especially as a means of holding solid particles and corrosion products in contact with the coating while it is being subjected to attack in a spray or other corrosive environment.

Exposure to a moist atmosphere carrying sooty smoke from high-sulphur fuel, followed by further exposure to a more normal moist atmosphere.

Exploration of the effects of temperature, between freezing point and some selected higher temperature, on the galvanic potential relationships among the basis and coating metals under consideration.

Study of influence of addition of a wetting agent, to favour penetration of corrosive media into fine pores or cracks.

Examination of coated specimens with regard to the amount of current required to prevent corrosion in an appropriate testing solution, e.g., sodium sulphate adjusted to suitable pH, or a solution collected from streets which have been treated with salt in winter.

Investigation of (1) positional effects in spray boxes (e.g., by moving specimens and/or nozzles); (2) effects of oxidizing agents other than air, in promoting breakdown of coatings in appropriate media; (3) waterline effects in connexion with immersion tests.

Experimental work already reported to the Committee has exonerated certain chemicals found in the air or on the streets from responsibility for corrosive attack, and has demonstrated the significance of others which contribute towards breakdown of coatings. A resumé is made of the nature of the attack made, on nickel plating, by some common industrial salts which may be present in the atmosphere or in substances coming into contact with plated parts under service conditions.

Detailed information on the preliminary tests will be published later. Meanwhile, the Committee invites suggestions from members of the Society with regard to other types of accelerated test which might merit inclusion in the research programme.

NON-FERROUS ALLOYS

Hydrometallurgy of Nickel and Other Base Metals

See abstract on p. 18.

Modern Uses of Non-Ferrous Metals

C. H. MATHEWSON (Editor): 'Modern Uses of Non-Ferrous Metals.' *Published by Amer. Inst. Mining and Metallurgical Engineers*, 2nd edn., 1953; 530 pp. Price £2 19s. 6d.

The 21 chapters in this book, dealing with individual metals, are contributed by authors closely associated with the most recent developments in the respective fields. The main object of the book is 'to give the young engineer a picture of the metal industry as it exists today': it is published under the auspices of the Seeley W. Mudd Memorial Fund Committee, which is sponsoring a series of books designed to meet the needs of the junior members of the engineering profession. In the 17 years which have elapsed since publication of the first edition progress has been made in extraction methods, there have been important advances in the science of alloying and heat-treatment, and many new materials have been evolved. Such developments are discussed in this volume.

Inclusion of individual metals has been on a selective basis, the general purpose being to cover those capable of exploitation as materials of construction in one form or another. Elements which are useful chiefly as small-scale additions to major metals, and those employed as intermediates in various industrial processes, have been excluded, together with metallic elements which are at present too rare for serious consideration.

The chapter on *Nickel* (by O. B. J. FRASER and P. D. MERICA, pp. 234–87) opens with a note on the development of nickel from pre-historic times to the present day, and on the general characteristics which make the element valuable in so many fields. Subsequent sections of the chapter give condensed reviews of the character and uses of malleable nickel and nickel plating, nickel–copper alloys (including Monel and cupro-nickel), alloys of nickel with iron, nickel-alloy steels of constructional and corrosion-resisting types; nickel-containing alloys showing special magnetic properties, nickel-alloy cast iron, nickel–chromium and nickel–chromium–iron alloys used in high-temperature applications, and age-hardening alloys. Since not all nickel is used for steel and alloys, attention is directed to its chemical applications, e.g., in storage batteries, as catalysts, and as a constituent of ground coats in vitreous enamelling.

Glossary of Foundry Terms

See abstract on p. 27.

Spring Materials: Properties of Nickel Alloys

HENRY WIGGIN AND CO., LTD.: 'Nickel Alloy Spring Materials.' *Publn.* 685,* 1953; 27 pp.

This publication, which replaces No. 252, opens with general notes on design of springs, and types of spring service for which various nickel-base alloys may be used. Suggested safe working stresses for cold-coiled nickel-alloy compression springs are tabulated, and consideration is given to particular conditions for which the respective materials are specially suitable, e.g., in damp or corrosive conditions, at sub-zero or at high temperatures, and in electrical equipment.

The second section of the publication contains a summary of the properties which are significant in relation to the application of nickel alloys as spring materials. Tables show ranges of room-temperature mechanical properties for spring wire and strip in the following materials: *Monel* (nickel-copper alloy), *K Monel* (nickel-copper alloy containing aluminium); *nickel*, *Inconel* (nickel-chromium-iron alloy), *Ni-Span 'C'* (nickel-iron alloy). Typical physical properties are also recorded in detail. Particular attention is drawn to developments which have taken place in nickel-chromium-base *Nimonic alloys* for springs, since issue of the earlier publication. Special interest attaches, in this connexion, to *Nimonic* 90 (nickel-chromium-cobalt-base alloy), which has proved outstandingly suitable for springs operating at high temperatures. The tables relating to this alloy give typical results of torsion and tensile tests on heat-treated bar, at temperatures over the range 20°–800°C.: particulars are also given of creep characteristics (100-, 300-, 1000-, and 5000-hour data).

The final section contains notes on manufacturing technique for the various alloys discussed, including coiling, heat-treatment, hot-working, and annealing

* *We shall be pleased to supply a free copy of this publication.*

practice. A centre insert comprises seven pages of design formulae which may be used as reference information in designing springs of any type of material.

Graphitic Nickel-Alloy Castings

J. T. EASH and G. L. LEE: 'Properties of Graphitic Nickel Alloy Castings.' *Trans. Amer. Foundrymen's Assocn.*, 1953, vol. 61, pp. 552–9; disc. p. 560.

Engineers are frequently confronted with the necessity of using a cast material which is corrosion–resistant and possesses anti–galling properties. This combination of qualities has been successfully developed in a group of nickel alloy castings containing carbon 1–2·5, silicon 2, manganese 1·5, per cent., with magnesium 0·05–0·10 per cent. in excess of sulphur. This paper gives a detailed account of the microstructure of such alloys (in which the graphite is in spheroidal form), and of the properties in relation to composition and structure. Comparative data are presented on magnesium–free alloys in which the graphite was present in flake form. An alloy of the composition given above has a tensile strength of about 60,000 p.s.i .(26·8 tons per sq. in.), with an elongation of 22 per cent., and the alloys can be further improved by additions of tin, which have a hardening effect on the matrix (see *U.S. Patent* 2,568,014).

Addition of tin causes increase in tensile strength, fall in toughness, and improved resistance to seizure on rubbing contact. Impact tests, using V–notched Charpy specimens, show values of 26–28 ft.–lb. for the nickel alloys in which the graphite was present in spheroidal form, by comparison with 9–13 ft.–lb. for flake–graphite alloys. In fatigue tests (in an R.R. Moore rotating–beam machine) smooth bars of the spheroidal–graphite alloy had an endurance limit of about 20,000 p.s.i., against 14,000 p.s.i. for those containing flake graphite. In square notched specimens the difference was less pronounced: 13,000 p.s.i. for the spheroidal–graphite alloys, by comparison with 12,000 p.s.i. for the flake–graphite type, indicating a greater notch–sensitivity in the higher–strength material.

The authors discuss the difficulties inherent in making gall tests which can be used to forecast the behaviour of materials in service, and describe plunger tests which they have found to give results approximating closely to service experience. Testing technique is detailed, and the apparatus is illustrated. The results showed that control of the amount and form of the graphite is important, in order to obtain full benefit from its lubricating action. A greater amount of spheroidal graphite is needed than of flake graphite, to obtain comparable anti–galling properties, but since the properties of the spheroidal–graphite nickel alloys are not appreciably affected by variations in carbon content up to 2 per cent., no objection arises to the use of an alloy containing 2 or even 2·5 per cent. of carbon. Addition of tin markedly enhances gall–resistance, particularly under heavy bearing loads, but a lower carbon range is desirable. An optimum combination of mechanical properties and gall–resistance is found in an alloy containing carbon 1, silicon 2, manganese 1·5, tin 2·5–4 per cent., 0·1 per cent. of magnesium in excess of sulphur, balance nickel.

Amsler wear tests, made under lubricated conditions, demonstrated that the tin–containing graphitic alloy in contact with itself or with S Monel (high–silicon Monel) performed excellently and showed little wear. When run against annealed wrought nickel seizure occurred quite rapidly, confirming the disadvantage of a soft homogeneous material in applications involving rubbing contact. Both the tin–free and tin–containing alloys were equally satisfactory when run against hardened steel.

Alloys of the types described can be easily cast into pressure–tight shapes having sharp definition and good surface quality. Details of suitable melting and casting practice are given.

Welding Rods and Electrodes Produced in U.S.A.

See abstract on p. 18.

Welding of Inconel

K. M. SPICER: 'Inconel: Which Welding Process Fits Your Job ?' *Iron Age*, 1953, vol. 172, Dec. 10, pp. 150–2.

The alloy Inconel (containing chromium 14–17, iron 6–10 per cent., with a minimum nickel content of 72 per cent.) can be welded by the various processes applicable to steel, with or without minor modifications. Mechanical properties which may be expected in Inconel welds made by the respective processes are shown in the table below.

This article makes practical recommendations on procedure which will ensure optimum results.

Welding Process	Tensile Strength		Yield Strength 0·2% Offset		Weld Metal Elongation on $\frac{1}{2}$ in. %	Hardness Rockwell B
	p.s.i.	t.s.i.	p.s.i.	t.s.i.		
Metal–Arc ..	97,000	43·3	54,000	24·1	37	90
Oxyacetylene ..	85,500	38·1	34,000	15·2	40	81
Inert–Gas Tungsten–Arc	94,750	42·3	45,000	20·1	40	84
Inert–Gas Consumable Electrode	85,125	38·0	37,200	16·6	50	83

Influence of Nickel Additions on the Corrosion-Resistance of Cast Copper-base Alloys

E. PELZEL: 'The Corrosion-Resisting Characteristics of Special Brass Casting Alloys.' *Metall*, 1953, vol. 7, Oct., pp. 767-71.

This paper reports a series of corrosion tests on (1) aluminium brasses containing additions of iron, manganese and nickel; (2) silicon brasses containing additions of lead, arsenic, manganese, or nickel; and (3) copper-zinc alloys (copper 50-60 per cent.) with additions of nickel and/or tin. Various combinations of the respective elements were used. The test solutions were 10 per cent. hydrochloric acid, synthetic sea water, and 3 per cent. sodium chloride solution containing 0·1 per cent. hydrogen peroxide.

Alloys of copper and zinc contents which placed them in the $\alpha+\beta$ range were found to show dezincification of the surface and a gradual build up of an incrustation of corrosion product. Additions of nickel to iron-containing aluminium brasses enhanced corrosion-resistance, as did the presence of nickel in silicon-containing brasses. Small amounts of arsenic also had a beneficial effect. Particular attention is directed to the excellent mechanical properties of the nickel-aluminium-iron brasses and the nickel-silicon brasses of the β region.

Condenser-Tube Alloys: Recent Development and Current Practice

See abstract on p. 37.

NICKEL-IRON ALLOYS

Influence of Ageing on Nickel-Aluminium-Cobalt-Iron Permanent Magnets

K. KRONENBERG: 'Investigations on Ageing, at Various Temperatures, of Permanent Magnets of Rod Form.' *Archiv f. d. Eisenhüttenwesen*, 1953, vol. 24, Sept.-Oct., pp. 441-6.

The investigations reported were planned to determine the stability of permanent magnets of the precipitation-hardening nickel-aluminium-(cobalt)-iron type. The compositions selected as typical are shown below, also the type of the chromium-cobalt steel with which comparative tests were made.

Alloy A was used in both the cast and sintered forms; the magnets from alloy B had been thermo-magnetically treated to produce a preferred orientation giving specially high energy value. The cobalt-steel specimen was typical of the older permanent magnets having martensitic structures. The materials tested included sintered nickel-aluminium-iron-base magnets in which an artificial binding medium having a specially high coercive force was incorporated.

Ageing treatments were carried out, for various periods and at temperatures varying from −190° to 500°C. : changes in structure and in apparent remanence were determined as functions of time and temperature.

In the nickel-aluminium-iron-base magnets very little structural change occurred on ageing so long as the temperatures were not within the precipitation-hardening range, whereas the alteration in the structure of the martensitic steel produced by heating under similar conditions was considerable.

Spring Materials: Properties of Nickel Alloys

See abstract on p. 25.

Nickel Alloys in Magnetic Pumps for Handling Corrosives

See abstract on p. 38.

CAST IRON

Glossary of Foundry Terms

AMER. FOUNDRYMEN'S SOC.: 'A.F.S. Glossary of Foundry Terms.' *Published by the Society, Chicago, Ill.*, 1953; 77 pp.

Price: Members 75c.; non-Members $1.25.

This glossary is the outcome of a project which has been under active prosecution by the Society since 1948. It is based on the experience and suggestions of a large and representative number of foundrymen in U.S.A. and on information obtained by consultation of existing glossaries and dictionaries of scientific and engineering terms used in many countries. Over 1,500 definitions are given.

Mechanical Properties of Acicular Nickel-Alloy Cast Iron

K. B. PALMER: 'Comprehensive Mechanical Tests on an Acicular Cast Iron.' *Brit. Cast Iron Research Assocn. Jnl. of Research and Development*, 1953, vol. 5, Dec., pp. 109-17; Research Rept. 371.

Continuing the Association's policy of publishing, at intervals, reports giving comprehensive data on the mechanical and physical properties of typical cast irons, this paper makes a review of the properties of

	Al %	Co %	Cr %	Ni %	W %	Fe %
(A)	13	—	—	27	—	Remainder
(B)	9	24	—	15	—	Remainder
(C)	—	2	4	—	0·6	Remainder

T.C. %	C.C. %	G.C. %	Si %	Mn %	S %	P %	Ni %	Mo %	Cu %
2·72	0·58	2·14	1·78	0·74	0·039	0·048	1·87	1·57	0·10

an acicular cast iron of the composition shown above.

The results presented include determination of tensile properties on plain, notched, and grooved bars; tests of hardness, impact–resistance, shear, torsion, damping capacity, compression and fatigue, and data on electrical resistivity, density and thermal expansion. Typical micro–structures are illustrated.

Corrigendum

Nickel Bulletin, Jan., 1954, p. 8. 'Impact Properties of S.G. Iron.' Sentence beginning on line 7 of abstract should read—

'The impact strength of notched bars falls steadily as the percentage of crystalline fracture increases, whereas that of *un*–notched bars does not begin to diminish until the fractures are almost completely crystalline.'

CONSTRUCTIONAL STEELS

Influence of Manganese, Nickel and Vanadium on Wear-Resistance of Steel

H. AREND: 'The Influence of Manganese, Nickel and Vanadium, in Conjunction with Carbon, on the Wear–Resistance of Normalized Steel.' *Archiv f.d. Eisenhüttenwesen*, 1953, vol. 24, Nov.–Dec., pp. 529–33.

The work reported in this paper was carried out to determine, on a comparative basis, the influence of a carbide–forming element (vanadium) with that of two elements which do not form carbides (nickel and manganese). The tests were made by the method developed by SPINDEL (see *Zeitsch. Ver. deutsch. Ing.*, 1926, vol. 70, pp. 415–21): the essential features of the test are described and illustrated in the present paper. Thirty–three steels were examined, eighteen containing vanadium (in amounts varying up to 4·84 per cent., with manganese in percentages normal in constructional steels), twelve containing manganese in amounts up to 10·12 per cent., without vanadium or nickel, and three containing, respectively, 2·00, 3·77 and 20·21 per cent. nickel, with normal percentages of manganese, but no vanadium. Full details of composition are given, together with data on the Brinell hardness of the steels in the normalized condition. Carbon, in the respective series, was varied from low levels up to slightly over 1 per cent.

Charts of the behaviour of each of the steels under test are given. The results lead to the conclusion that in the normalized condition, in which all the steels were tested, carbon content is the factor which primarily determines resistance to wear. The behaviour of the vanadium–containing steels showed also that only the vanadium which is not combined with carbon has any influence on wear–resistance. Comparison of the behaviour of the nickel and the manganese series showed that, at equal carbon contents and a given content of manganese or nickel, manganese has the greater influence on wear–resistance. At Brinell hardnesses up to 300 increasing hardness was found to be associated with improving resistance to wear. At hardnesses above 300 vanadium steels showed the better resistance to wear, but at hardness levels below 300 Brinell the manganese steels were more resistant.

Welding Rods and Electrodes Produced in U.S.A.

See abstract on p. 18.

Absorptiometric Determination of Cobalt in Nickel-Alloy Steels

BRIT. IRON AND STEEL RESEARCH ASSOCN. METHODS OF ANALYSIS COMMITTEE: 'Absorptiometric Determination of Cobalt in Iron and Steel.' *Jnl. Iron and Steel Inst.*, 1954, vol. 176, Jan., pp. 63–6.

Cobalt in steels is usually determined gravimetrically by precipitation of the element with nitroso β–naphthol and subsequent ignition to cobaltic oxide under carefully controlled conditions. Preliminary separation of the iron group is a necessary factor of the procedure.

The method is tedious and sometimes gives low results owing to the adsorption of cobalt by the hydrolysed iron group, even after a double precipitation, and also by tungstic acid when present. The need for a more accurate and convenient method led to the examination of absorptiometric procedures, among which the method of HAYWOOD and WOOD (*Jnl. Soc. Chem. Ind.*, 1943, vol. 62, pp. 37–9) appeared to be promising. This, unlike many of the others considered, does not involve an iron separation, but relies upon the development of a red cobalt complex in neutral or buffered solution by the addition of nitroso–R–salt (sodium 1–nitroso–2–naphthol–3 : 6–disulphonate). Tungsten is retained in solution by phosphoric acid.

This method had already been used in a modified form to determine very small quantities of cobalt, and its operation on a wider scale was considered to merit detailed study. The investigation reported in the present paper was carried out by the Physico–Chemical Methods of Analysis Sub–Committee of B.I.S.R.A. The method recommended differs from the original Haywood and Wood procedure in that the boiling period for destruction of interfering ions is eliminated, different light filters are preferred, and reagent additions are adjusted to compensate for the presence of interfering elements. The steels used in the investigation comprised representative types permitting study of the influence of various elements, including nickel in small and large percentages.

The revised method (of which full details are given in the paper), is to be recommended for adoption as a British Standard.

Mercury-Cathode Electrolysis of Steel

BRIT. IRON AND STEEL RESEARCH ASSOCN., METHODS OF ANALYSIS COMMITTEE: 'Mercury–Cathode Electrolysis and its Application to Steel Analysis.' *Jnl. Iron and Steel Inst.*, 1954, vol. 176, Jan., pp. 29–36.

The report describes a method for mercury–cathode electrolysis, applicable over a wide range of alloy steel compositions. Optimum conditions for removal of large amounts of cathodically deposited elements, e.g., iron, chromium, and nickel, are described. Experimental evidence shows that after electrolysis the solution can be used for the quantitative determination of various trace elements, e.g., aluminium, titanium, vanadium, and zirconium.

Heat-Resisting Alloy Steels: Compositions, Properties and Uses

See abstract below.

U.S. and British Comparative Creep Tests on High-Temperature Steels

See abstract on this page.

HEAT- AND CORROSION-RESISTING MATERIALS

Heat-Resisting Materials: Compositions, Properties and Uses

C. G. CONWAY: 'Heat-Resisting Steels and Alloys. A Concise Data Book giving the High-Temperature Properties of Commercial Steels and Alloys.' *Published by George Newnes, Ltd.*, London, 1953; 160 pp. Price 25/–.

During the past 20 years there has been an ever-increasing demand for adequate data on which to base design of engineering components required to operate under stress at high temperatures. In particular, knowledge of the creep characteristics of steels and alloys is important.

Phenomena associated with behaviour at high temperatures have been the subject of intensive study during the war and post-war periods, and valuable information has been published in Great Britain, U.S.A., Germany and other countries, but much of this is scattered over a wide range of scientific and technical literature. The author of the present book, who has for many years been closely associated with both the academic and the practical study of high-temperature materials, has assembled in this volume authoritative data collected from many sources, and has critically evaluated the experimental results and service experience, with a view to placing at the disposal of the engineer reference material which may with confidence be utilized in design. Among the useful features of the book are the attention directed to the inter-relation of mechanical and physical properties, as influenced by temperature, and the emphasis which is placed on the many factors which must be taken into account in estimating the suitability of a given material for service under specified conditions of temperature and stress.

Section 1 contains notes on the *arrangement of the data* in the book, and on the *creep phenomenon* and methods used for reporting creep data. Section 2 includes a collection of *general tables and curves* relating to thermal conductivity, thermal expansion, creep, Young's modulus, and conversion factors covering units employed in reporting the information in later chapters.

The main portion of the book is in seven sections, covering, respectively, the composition and properties of the following types of material:—

Carbon and Low–Alloy Steels
Bolt Steels
Valve Steels
Austenitic Steels of Standard Types
Special Heat–Resisting Steels and Alloys of Proprietary Types
(*a*) Iron–base Alloys.
(*b*) Nickel–base Alloys.

A general guide is given to the oxidation–resistance of the various groups of materials at service temperatures, and in each section detailed information is provided, in tabular and graphical form, on the composition, uses, advantages and disadvantages of the individual materials, their creep characteristics, and their physical and mechanical properties.

The book constitutes a ready–reference source of information which will be of practical value to engineers concerned with design in many branches of engineering, including jet aircraft engines, power plant, furnaces, steam boilers, and many types of chemical plant operating under stress at high temperatures.

U.S. and British Comparative Creep Tests on High-Temperature Steels

W. E. BARDGETT and C. L. CLARK: 'Comparative High–Temperature Properties of British and American Steels.' *Instn. Mechanical Engineers, Advance Copy*, Dec., 1953; 6 pp.+figures: also presented before Amer. Soc. Mechanical Engineers, Dec., 1953.

In view of the substantial differences often found in data for steels of similar composition published in Britain and the U.S.A., arrangements were made for co–operative tests of identical specimens in the laboratories of The United Steel Companies, Ltd., and The Timken Roller Bearing Company, Ohio, (*a*) to determine the extent of the agreement attained by testing under the conditions used in the two laboratories, and (*b*) to evaluate the creep–resisting properties of typical steels.

Five representative high–temperature steels were selected, as being in general use in both countries, and each was tested at a single temperature, corresponding to the one at which the material is normally used. Only one stress was imposed (of an order somewhat higher than the working stress) for each of the creep tests, and it was maintained for a minimum of 1,000 hours. No attempt was made to standardize testing procedure between the co–operating laboratories, since it was one of the objectives of the work to determine variations in results which might arise from normal differences in testing techniques.

The typical steels chosen for test were: 0·50 molybdenum; 2¼ per cent. chromium+1 per cent. molybdenum; 5 per cent. chromium+molybdenum and titanium; niobium-stabilized 18–12 chromium–nickel; 25–12 chromium–nickel. Steels of these types produced in each country were tested by both laboratories, with the exception of the 2¼ per cent. chromium–1 per cent. molybdenum steel, of which no American specimen was available for the British tests. Details of production methods, variations in composition, and heat-treatment are given, and the results obtained in the individual creep tests are summarized in tables and graphs.

Critical consideration of the results leads the authors to the conclusion that American and British laboratories can usefully check one another in determination of the creep characteristics of ferritic steels, but that quite substantial differences can be found in tests of similar austenitic steels made in laboratories in the two countries. The lack of agreement in the case of the austenitic steels is attributed to their greater sensitivity to variations in the period of heating used prior to testing and to differences in rate of loading. It is recognized that even in any one laboratory these conditions must be closely controlled in order to ensure reproducibility of results on austenitic steels.

The data reported also indicate that creep properties of steels of the same composition are not always identical. Only three of the ferritic steels came into this category: good agreement was found with two of them, whilst the third showed quite a marked difference. A further observation is that steels of similar type show substantial differences in creep behaviour. In the two austenitic steels, which are the types falling into this category, differences in grain size as well as in composition are likely to have been a significant factor.

See also

R. W. BAILEY, 'A Critical Examination of Procedures used in Britain and the United States to Determine Creep Stresses for the Design of Power Plant for Long Life at High Temperatures'. *Instn. Mechanical Engineers, Advance Copy*, Dec., 1953; 13 pp.

This paper, presented at the same meeting as the report referred to in the preceding abstract, draws attention to the fact that since the operating life of land power plant is far longer than the times possible in testing, the selection of a material, or the determination of its appropriate working stress, is dependent to an important degree upon the procedure followed in utilizing creep-test results for design. Different procedures followed, both in Britain and in U.S.A., may result in different conclusions being drawn with regard to the suitability of materials for specific applications, and the working stress permissible. The author of this paper examines the test methods in common use, with particular reference to factors which may operate to introduce uncertainty and error as between the results of test and the probable behaviour in long-time service. It is pointed out that the principal factor influencing resistance to creep is thermal action, and that test procedure, if it is adequately to assess suitability for long-term operation, must take account of the thermal effects which will be present in service conditions. A further important source of error is the method of extrapolation beyond the test times to the times of operating life: this is also discussed.

Marine Gas Turbines: Design, Materials, and Service Experience

(1) B. E. G. FORSLING: 'The Marine Gas Turbine.' *Trans. Inst. Marine Engineers*, 1953, vol. 65, Nov., pp. 265–73.

By mutual arrangement among the authors, this paper is to be regarded as complementary to the one referred to in the second abstract under this heading, since the two papers refer to different aspects of the same subject. FORSLING's paper constitutes an introduction, giving background and theory; the paper by LAMB and DUGGAN is mainly devoted to results obtained in the working of a gas turbine under sea conditions.

Paper No. 1 reviews the considerations which govern design of marine gas turbines, and indicates the reasons which necessitate the use of austenitic materials for blading and other components subject to high service temperatures. A detailed description is given, with diagrams, of the main propulsion gas-turbine set installed in the tanker 'Auris', and of tests made before the set was put into commission. A brief summary is also made of her sea trials, but this aspect is more fully dealt with in the second paper. The final section of the paper discusses the design of large main propulsion gas-turbine sets of improved thermal efficiency.

(2) J. LAMB and R. M. DUGGAN: 'Operation of a Marine Gas Turbine under Sea Conditions.' *Inst. Marine Engineers, Advance Copy*, Nov., 1953; 16 pp.

This paper describes the results obtained, over a period of two years, with the gas turbine of the 'Auris', which was the first to be used for propulsion of a merchant ship. It went into operation in October, 1951, and has since then worked under sea conditions normally encountered in all parts of the Western hemisphere, covering 115,000 nautical miles.

After general observations on the design of the unit, each component is separately discussed, and methods adopted to maintain them in working condition are reviewed. Particulars are given of observations made during periodic inspections, with a description of the nature and extent of the corrosion suffered by the heat-resisting steel turbine blades due to attack by fuel ash containing vanadium pentoxide and other constituents. The observations made to date have indicated that for the h.p. turbine blading high-nickel alloys, e.g., of the Nimonic 80A type (which have now been installed) are likely to give longer life than that obtained with the heat-resisting steels initially used. A high-nickel alloy of the same series (Nimonic 75) has also proved more serviceable than a heat-resisting steel for the mixing-zone shells.

The results of the tests made to date are considered to justify the conclusion that 'there is nothing in the operation of a marine gas turbine which is beyond the capacity of the average ship's engineer: that the gas turbine is not affected mechanically by any conditions

likely to be encountered at sea in any part of the world, and that there is no reason why future gas-turbine installations should not operate continuously on the longest voyages. Apart from defects in materials and workmanship, the life of the major parts (h.p. turbine blades excepted) of a conservatively rated installation will not be less than the life of the ship, and a life of not less than 10,000 hours may be confidently expected from h.p. turbine blades if made of the best material now procurable.' Vis-à-vis other forms of marine propulsion, the main advantage of the gas turbine is likely to be its low maintenance cost.

Production of Gas-Turbine Blades in High-Nickel Alloys

B. P. DABELL and L. H. WILLIAMS: 'Production of Gas-Turbine Blades. Techniques adopted by Ruston and Hornsby, Ltd., Lincoln.' *Metal Treatment*, 1953, vol. 20, Dec., pp. 571–8.

The first part of this article outlines the early history of development of gas turbines at the works of Ruston and Hornsby which led to selection of the methods now standard. The second part describes, in detail, the methods now employed.

The problem of quantity production of gas-turbine blades first arose at this works in 1946, in connexion with the design of the Ruston Mark 3CT unit, which was one of the first industrial gas turbines to be run in England.

The authors review the various methods which may be used for blade manufacture and critically discuss their relative advantages and limitations, which led to standardization, in the Ruston and Hornsby works, of the method of machining direct from bar. For the stator blades of the turbines Nimonic 80 is used, and for the rotor blades Nimonic 80A. Compressor rotor blades and intermediate stator blades are machined from 13 per cent. chromium steel to B.S. En 56 A-Q, with the exception of the first and last rows of stator blading, which are in austenitic chromium-nickel heat-resisting steel (H.R. Crown Max.). Compressor stator exit blades and inlet guide vanes, being small in number, larger in chord (thus more robust and easier to clamp for machining), and less critical from the point of view of accuracy, are precision-cast in 20-12 chromium-nickel steel. The equipment used, and the sequence of operations involved in production of the respective components, are described, with illustrations, and some account is given of the drastic inspection to which the blades are subjected before being passed for service.

Corrosion of Austenitic Nickel-Chromium Steels by Vanadium Pentoxide

F. C. MONKMAN and N. J. GRANT: 'An Investigation of Accelerated Oxidation of Heat-Resistant Metals due to Vanadium.' *Corrosion*, 1953, vol. 9, Dec., pp. 460–5; disc. 465–6.

Following a short review of some of the outstanding literature on corrosion by vanadium pentoxide, the authors report tests made to determine the possibility of inhibiting attack by addition, to the fuel ash, of various refractory metal oxides. The material on which the tests were made was steel of A.I.S.I. Type 316, which, by reason of its molybdenum content, gave a reaction rate more rapid than that obtainable with Types 347 and 321 (molybdenum-free grades). A synthetic oil ash of the following composition was used.

	%
V_2O_5	60
Na_2SO_4	15
CaO	10
SiO_2	5
Fe_2O_3	5
PbO	5

To this were added, singly, varying amounts of the oxides MgO, CaO, NiO, ZrO_2, CrO_2O_3, TiO_2, ZnO, Al_2O_3 and SiO_2. Determinations of the melting points of these mixtures showed that the oxides of magnesium, calcium and nickel raise the melting point of the ash considerably. Up to 50 per cent. of aluminium oxide, zinc oxide and silica had no measurable effect, and the oxides of zirconium, chromium and titanium, in amounts up to just over 20 per cent. raised the melting point only slightly. The inhibition tests were therefore made with the three beneficial oxides only, i.e., those of magnesium, calcium, and nickel. A description is given of the cupped specimens of steel used for the tests, and the experimental conditions and equipment are illustrated. The investigation covered also a study of the role of Na_2SO_4, in admixture with V_2O_5: the tests in this series were made on nickel and on Type 347 stainless steel. Further experiments were designed to elucidate the mechanism of the accelerated corrosion resulting from contact with vanadium pentoxide, and to determine the nature of the metal–vanadium–oxygen compound found at the metal–oxide interface in corroded materials.

From the results of the various experiments the authors draw the following conclusions:—

'(1) The oxides of calcium, magnesium and nickel form high-melting compounds with V_2O_5, and are capable of inhibiting accelerated oxidation.

'(2) Na_2SO_4 promotes accelerated oxidation below the melting point of V_2O_5, by forming a liquid phase with the latter, but at temperatures above the melting point of V_2O_5, the presence of the sulphate inhibits accelerated oxidation.

'(3) In contrast to normal oxidation, the oxide structure at the metal–oxide interface is oxidized to a higher level than the structure at the atmosphere–oxide surface.

'(4) There exists a critical partial pressure of oxygen below which accelerated oxidation does not occur.

'(5) The concentration of vanadium in the oxide scale was found to increase as the metal–oxide interface was approached.

'(6) A metal–vanadium–oxygen compound, having the orthorhombic $VCrO_4$ structure, has been found near the metal–oxide interface. It has been proposed that this structure is in equilibrium with a thin molten film high in vanadium, which is the corrosive medium in accelerated oxidation.'

Inconel Pots for Alkali Fusions

R. S. YOUNG and K. G. A. STRACHAN: 'Inconel Pots for Alkali Fusions.' *Metallurgia*, 1953, vol. 48, Dec., p. 318.

In the cleaning of diamond powder after crushing, and its reclamation from industrial wastes, it is frequently necessary to fuse substantial quantities of the powder with potassium or sodium hydroxide, over a gas burner. Pots of cast iron and of stainless steel employed for this purpose have been found unsatisfactory, for reasons which are given in this note. Laboratory tests on welded pots of Inconel, $\frac{3}{32}$-in. in thickness, have proved them to be (*a*) more resistant to corrosion than either cast iron or stainless steel pots, and (*b*) free from any tendency to contaminate the product, a problem which had arisen with the cast iron pots. The rate of corrosion of Inconel pots was measured over a period of 24 hours, the criterion of attack being the amount of nickel found in the fusion of a nickel-free synthetic mixture containing caustic alkali and the materials usually found in the cleaning of diamond powder and in its recovery from wastes. These included silica, silicon carbide, aluminium oxide, iron and other metals, tungsten carbide, graphite, dust and dirt. This mixture (50 g.) was added to 600 g. of caustic alkali, and fusion was carried out during eight hours, on three successive days. At the end of each day the contents of the pots were emptied and a fresh fusion mixture was used on the following day. Under such conditions the rates of corrosion were 193 mg./sq. dm. per day for sodium hydroxide fusions, and 189 mg./sq. dm. per day for potassium hydroxide fusions. Attack was uniform: no pitting or etching of the surface was observed. Such rates of corrosion are considered highly satisfactory, assuring long life of the pots, and a minimum of contamination. Inconel is strongly recommended for this application.

Nickel-Chromium Electrical-Resistance Alloys in Domestic Heating Elements

H. HODGES: 'Domestic Heating Elements. Trends in the Development of Nickel-Chromium Alloys.' *Henry Wiggin and Co., Ltd., Publn.* 707,* 1954; 8 pp.

Reprint of paper from *Electrical Review*, 1953, vol. 153, pp. 607–12: see abstract in *Nickel Bulletin*, 1953, vol. 26, No. 12, p. 213.

Spring Materials: Properties of Nickel Alloys

See abstract on p. 25.

Carbon Dioxide Cooling in Machining of High-Temperature Alloys

'The CeDeCut Carbon Dioxide Cooling Technique.' *Machinery (Lond.)*, 1953, vol. 83, Dec. 25, pp. 1239–43, 1285.

In connexion with difficulties inherent in machining of high-alloy materials, considerable interest has developed in the possible use, as coolants, of liquified gases. Attention was earlier directed in *Machinery* to the potential value of carbon dioxide as a cooling medium, and the present article gives a detailed description of equipment and procedure developed for its effective application in commercial operation.

Welding of Austenitic Steel Piping for High-Temperature Service

W. G. BENZ and R. H. CAUGHEY: 'Fabrication of Austenitic Stainless Steel Steam Piping for Operation at 1100°F.' *Amer. Soc. Mechanical Engineers, Paper* 53-*SA*-58, June-July, 1953; 17 pp. + tables and figures.

In the past few years, with the advent of steam temperatures up to 1100°F. (595°C.) and pressures up to 2,350 p.s.i., the electric power-generating industry has become an important user of the austenitic stainless steels for piping equipment. Currently the 18-10 chromium-nickel niobium-stabilized type is favoured, and in the course of its application a number of problems associated with fabrication, welding, and heat-treatment have arisen. Among these is the incidence of cracks in weld deposits, and, in a lesser degree, in base metal.

Laboratory tests and the examination of specimens of material after extended service at 1050°F. (565°C.) have shown that the embrittlement of ferrite-bearing austenitic weld deposits is due largely to formation of sigma phase. This paper reports a study of the following means of inhibiting such change in structure:—

(1) Use of electrodes of controlled composition which will deposit a fully austenitic crack-free weld.
(2) Use of electrodes of controlled composition which will deposit a crack-free weld containing less ferrite than is normally specified as necessary.
(3) High-temperature post-welding heat-treatment, to dissolve or coalesce the ferrite phase, and thereby inhibit or make ineffectual any sigma subsequently formed.

Five 18-10 niobium-stabilized electrodes were used, four designed to deposit a fully austenitic weld and the fifth to produce a deposit containing about 1–4 per cent. ferrite. Weld deposits made with these electrodes, on 18-10-Nb forged and bored heavy-wall piping, were compared with regard to crack sensitivity and response to post-weld heat-treatment. The evaluation was made by mechanical tests and microscopical examination of samples which had been subjected to short- and long-time ageing (1) above service temperatures, and (2) at service temperatures. The authors make the following summary of their findings:—

(1) Weld joints produced were in each case consistent with A.S.M.E. X-ray requirements. Crater cracking, in the fully austenitic deposits, was the only significant defect found.
(2) Tensile and Charpy impact tests on the as-welded deposits showed properties satisfactory for power-piping use. In 'side-bend' tests cracks developed in all cases: the fully austenitic deposits showed the greatest tendency to cracking.
(3) After ageing at 1100°F. (595°C.) for 1,000 hours, or at 1350°F. (735°C.) for 300 hours (equivalent to about 20,000 hours at 1100°F.), all as-welded deposits showed a marked reduction in notch toughness. This treatment produced no significant

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changes in the tensile properties, but increased cracking was observed in side-bend tests.

(4) Stress-relieving at 1750°F. (955°C.), prior to ageing at 1350°F. (735°C.), did not improve the properties exhibited by the as-welded deposits after ageing.

(5) Solution treatment at 1950°F. (1065°C.), prior to ageing at 1350°F. (735°C.), resulted in marked improvement in notch toughness of one fully austenitic deposit, and in the single ferrite-bearing deposit. After such treatment less cracking was observed in the side-bend tests of the ferrite-bearing deposit. In the fully austenitic deposits which did not respond to solution treatment the influence of higher percentages of carbon, niobium, and silicon is thought to be significant.

(6) The presence of intergranular carbides and of unidentified phase, in the fully austenitic deposits, is suggested as the cause of the embrittlement observed. Sigma formation in ferrite-bearing deposits is apparently responsible for embrittlement, although the effect of precipitated carbides is not discounted.

On the basis of the observations made it is recommended that, for welding the 18–10–niobium–stabilized type of piping, ferrite-bearing electrodes of the same type of steel be used, the composition of the electrode being balanced to give a deposit containing 1–4 per cent. ferrite. The following limits of composition for the deposit are suggested:—

Carbon 0·07–0·10, silicon 0·60–0·90, niobium 5 × C.

A post-welding heat-treatment at 1950°F. (1065°C.) is recommended for niobium-stabilized 18–10 which is to operate at high temperatures; optimum conditions are considered to be as follows: rapid heating to 600°F. (315°C.); heating at a rate not exceeding 300°F. (167°C.) per hour from 600°F. to 1100°F. (315°C. to 595°C.); holding for 2 hours at 1000°–1100°F. (540°–595°C.); continued heating to 1950°F. (1065°C.) at a minimum rate of 600°F. (334°C.) per hour; holding at 1950°F. (1065°C.) for 2 hours; air-cooling from that temperature as rapidly and uniformly as possible.

The second part of the report describes in detail shop fabrication of piping assemblies, according to the recommendations resulting from the tests recorded in part one.

Repair Welding of Ceramic-Coated Nickel-containing Materials

J. M. RIORDAN: 'Repair Welding of Ceramic-Coated Alloys.' *Welding Jnl.*, 1953, vol. 32, Dec., pp. 1160–6.

The higher temperatures now regularly imposed by service in aircraft jet engines have given rise to much interest in the use of ceramic coatings for protection of metallic materials at temperatures above those at which the latter can safely be used in the bare condition. Use of such coatings has brought to the fore problems involved in repair-welding of ceramic-coated parts damaged in transport, assembly, or service. This paper records a practical investigation of the welding of materials coated with Solaramics, the ceramics developed by Solar Aircraft Company.

The processes studied included inert-gas-shielded arc and oxyactylene-gas welding of typical heat-resisting alloys, and of a material of lower alloy content. These representative materials were austenitic nickel-chromium steels (18–8 chromium-nickel titanium-stabilized, and 25–20 chromium-nickel); Inconel (nickel 72, chromium 14–17, iron 6–10 per cent.); Haynes Stellite N-155 Multimet (chromium 20–22·5, nickel 19–21, cobalt 18·5–21, molybdenum 2·5–3·5, tungsten 2–3, per cent., with small amounts of carbon, manganese, silicon, niobium and nitrogen, balance iron); and Timken Sicromo 5S (4–6 per cent. chromium steel containing molybdenum 0·45–0·65 per cent.).

Defects considered most likely to occur in repair welding of ceramic-coated parts include cracks, non-fusion, and inclusion of entrapped ceramic constituents. The examination of the welds was therefore planned to detect such imperfections. Visual examination, and metallographic study of unetched and etched cross-sections gave the following results:—

18–8 Stainless Steel: All welds of good quality; no cracking or other defects discernible and no slag inclusions observed.

25–20 Stainless Steel: Welds were of inferior quality, exhibiting numerous intergranular fissures, the examination of which revealed the presence of non-metallic inclusions.

Inconel: Welds of poor quality, exhibiting many intergranular cracks, accompanied by non-metallic inclusions.

Haynes Stellite N–155: All welds were free from defects and showed uniformly good quality.

Sicromo 5S: Due to the air-hardening properties of this material, the microstructure of the welds was definitely martensitic, but all welds were of good quality, showing, under the microscope, no evidence of cracking or inclusions.

The results, which are well illustrated by typical photomicrographs, are critically discussed in relation to the composition of the respective basis materials, particular attention being directed to the nickel and silicon contents, which have been shown, in experiments on the welding of uncoated materials, to be of significance. The observations made lead to the following recommendations with regard to repair-welding of ceramic-coated materials in the field:—

'For oxy-acetylene gas welding of the 18–8 steel, N-155 and Sicromo 5S or similar low-alloy materials, the repair area should be cleaned as thoroughly as possible by such means as washing with gasoline, carbon tetrachloride or other cleaning solvent, wire-brushing, or application of emery cloth or other abrasive. If a patch is necessary, it should be clean and all burrs should be removed. While the Solaramic coat will give protection against oxidation during the welding cycle, it will have no scavenging action, so that it is desirable to use a good welding flux, on the underside.

'Following the welding cycle, the welds and adjacent area should again be wire-brushed or otherwise cleaned. A small amount of Solaramic slip may be used as an abrasive in this operation. The area then may be covered with slip, and the torch used to fire the slip into a tough, thin, protective coating.

'The process for inert-gas-shielded arc would be

similar. Of course, the coating could not be replaced without some means of controlled firing, such as is available when gas welding is used. Metallic-arc welding may be successfully used if fluxing precautions are observed.

'When 25-20 chromium-nickel steel or Inconel must be repaired in the field, the ceramic coating should be chipped and brushed away from an area extending at least ½ in. around the repair area, for either torch or arc repair, and the underside of the area should be thoroughly fluxed for torch or metallic-arc repair. The Solaramic coating can be replaced on these alloys by the steps outlined above.'

Welding of Stainless Steels: General Recommendations

R. E. SOLOMON: 'Proper Technique Gives Stainless Good Weldability.' *Iron Age*, 1953, vol. 172, Dec. 10, pp. 142–4.

The writer opens with notes on the importance, to the welder, of a general knowledge of the fundamental characteristics and properties of stainless steels, particularly of the difference between the stainless and carbon steels. A graph illustrates the electrical resistances, coefficients of expansion, melting points and thermal conductivities of carbon, austenitic chromium–nickel and straight-chromium types. Avoidance of rods of large diameter, and of weaving (except in particular cases) is urged: use of low current and stringer-bead technique is advocated. A short arc is recommended, in order to obtain maximum benefit from the flux used; welds so produced show superior corrosion-resistance and better appearance than those made with a longer arc. Careful edge preparation of thick material is essential, and although most of the welding may be done from one side, the author favours the laying of a small cover-up bead on the other side. Pre-heating is frequently beneficial when welding crack-sensitive types of stainless steel, and in cold weather the steel should always be brought to at least room temperature before welding. Clean surfaces are essential for successful joining, and an effort should be made to facilitate finishing operations, e.g., by reducing spattering to a minimum.

Inert-Tungsten Arc Welding of Nickel-Chromium Stainless Steel Piping

F. J. PILIA: 'Inert-Tungsten Arc Welding of Stainless-Steel Piping.' *Welding Jnl.*, 1953, vol. 32, Dec., pp. 1167–74.

During the past few years considerable progress has been made in eliminating backing rings from welded piping assemblies. This article gives a detailed summary of practice by which it is possible to produce, on the inside of an inert-tungsten arc-welded stainless steel pipe joint, a surface which is smooth and free from obstructions and notches. Pipes welded by the methods described require no finishing, and are claimed to be satisfactory for handling corrosive fluids, high-pressure and high-temperature steam, fluid metals, food, and pharmaceutical products. The technique described is at present limited to use on the 25-20 chromium–nickel austenitic stainless steel, but it is being adapted to be applicable to welding of carbon steel, chromium steel and low-alloy steel piping.

Stabilization of Chromium-Nickel Weld Metal by Increased Chromium

H. C. CAMPBELL: 'Stabilizing Austenitic Chrome-Nickel Weld Metal against Intergranular Corrosion.' *Welding Jnl.*, 1953, vol. 32, Dec., pp. 577S–83S; disc., pp. 583S–4S.

During the recent shortage of niobium, ferro-tantalum–niobium proved, in most applications, to be an efficient stabilizer of austenitic steels, but in welding such modification was not satisfactory due to excessive losses occurring across the arc, which resulted in no real conservation of niobium. Titanium is an alternative to niobium in many cases, but the titanium–stabilized type of austenitic steel cannot be used in welding electrodes because the titanium is almost entirely oxidized in the electric arc, giving rise to an unstabilized weld deposit. The niobium-stabilized electrode is therefore preferred even for welding titanium–stabilized steel.

It has been known for some time that titanium can be transferred across the arc when it is adequately protected by a more active metal, such as aluminium, but the usability of electrodes to which sufficient aluminium has been added is not good; the aluminium is preferentially oxidized in the arc, and the resulting alumina produces a slag which has undesirable characteristics.

The investigation reported in the present paper was prompted by the idea that it might be possible to secure adequate stabilization of 18–8 weld metal by using titanium with a supplementary addition of some other stabilizing element. Three possible alternatives were considered: use of one of the carbide-forming elements, vanadium, zirconium, or chromium. Exploratory trials showed both vanadium and zirconium to be unsuitable (for reasons which are detailed in the report), thus narrowing the practical possibility to the use of chromium. Electrodes containing about 10 per cent. of nickel, with varying carbon, chromium, and titanium, were examined. Determinations of ferrite content were made, and the weld deposits were subjected to (*a*) boiling nitric acid and (*b*) nitric–hydrofluoric acid tests, each type of weld metal being tested in the as-welded, stress-relieved, stabilized, annealed, and annealed–sensitized conditions. Tensile properties were also determined.

On the basis of the results of these tests, an electrode depositing chromium 22, nickel 10, per cent. is proposed as a substitute for niobium-stabilized electrodes, in applications where resistance to intergranular corrosion is of importance. The screening tests reported show low rates of corrosion for welds made with electrodes of this composition, both in the as-welded and heat-treated conditions, and the room-temperature mechanical properties of the deposits are above those required by the A.W.S./A.S.T.M. electrode specifications. It is recommended that field tests be made. (It is specifically stated that where service conditions require

the use of niobium–stabilized steel as the parent material there would be 'less inclination to recommend a substitute for the standard niobium–stabilized austenitic steel electrode.')

In discussion, A. J. ROSENBERG reported experiments in which molybdenum–stabilized steel had shown promise of being, in some cases, a useful substitute for the niobium–stabilized type. He also raised the possibility of a tendency to sigma formation being induced by the higher chromium of the modified electrode proposed by the author.

Welding Rods and Electrodes Produced in U.S.A.

See abstract on p. 18.

Influence of Deformation at Sub-Zero Temperatures on the Properties and Structure of Austenitic Steels

F. BUNGARDT, R. OPPENHEIM and R. SCHERER: 'Influence of Deformation at Low Temperatures on the Properties of Corrosion-Resisting Austenitic Steels.' *Archiv f.d. Eisenhüttenwesen*, 1953, vol. 24, Sept.-Oct., pp. 423–30.

Recent investigations in Germany and the U.S.A. have indicated the beneficial effects which may be secured by mechanical working of austenitic steels at sub-zero temperatures (see, for example, abstracts of papers by ZIEGLER and BRACE, and by KRIVOBOK and TALBOT (*Nickel Bulletin*, 1950, vol. 23, Nos. 8–9, p. 168; and 1951, vol. 24, No. 4, p. 88). The researches reported by the above authors have demonstrated that the γ to α change in such steels is promoted by working at sub-zero temperatures, the degree of the effect being dependent on the composition of the steels and their resultant structural stability. By working at these low temperatures it is possible, by a given amount of deformation, to produce higher yield and tensile strengths and greater hardness than are producible by identical treatment at room temperature, and the ductility associated with a given level of strength and hardness is greater in steels mechanically worked at sub-zero temperatures than in steels of identical composition which have been worked at normal temperature. A further advantage, which is of economic significance, is that the amount of work required to produce a given tensile strength is less if carried out at sub-zero temperatures. Subsequent low-temperature annealing (at about 400°C.) still further raises the mechanical properties of steels so treated.

The tensile and rolling tests reported in the present paper were carried out to ascertain the response, to sub-zero mechanical working, of steels typical, in composition, of corrosion-resisting steels in current supply and varying, therefore, in austenite stability. The investigation comprised two methods of cold-working: (1) drawing down of wire, of 2·3 and 4 mm. initial diameter, and (2) rolling of sheet having an original thickness of 2·75–3 mm. In both cases the work was done at (*a*) room temperature, (*b*) about −70°C., and (*c*) about −180°C. After determination of the mechanical properties of the materials in the cold-worked conditions, they were annealed at 400°C. for 24 hours, and the mechanical properties were again examined.

The compositions of the steels used are shown below.

Tables show the mechanical properties of the materials in the initial condition, after cold-working at the various temperatures, and after annealing. Curves relating to the niobium-stabilized nickel-chromium

Chemical Composition of the Steels Investigated

Steel(1)	C %	Si %	Mn %	Cr %	Mo %	Ni %	Nb–Ta %	Ti %
A	0·14	0·56	0·70	17·98	0·10(2)	7·30	—	—
B	0·06	0·42	0·58	17·26	0·07(2)	11·27	—	—
C	0·075	0·62	0·41	17·54	0·21(2)	10·34	0·81	—
D	0·07	0·35	0·43	18·33	2·21	8·34	—	—
E	0·06	0·56	1·32	18·30	2·19	11·82	—	—
F	0·10	0·56	1·29	18·02	2·23	11·93	—	0·53
G	0·08	0·66	0·36	17·06	1·85	10·47	0·87	—
H	0·11	2·54	0·36	18·50	2·15	9·16	—	—
J	0·085	0·64	8·92	14·50	0·15(2)	2·14	—	0·09(2)
I	0·06	0·37	0·91	18·00	0·14(2)	9·98	—	—
II	0·06	0·42	0·69	17·48	0·08(2)	9·96	0·52	—
III	0·14	0·86	18·52	12·37	0·75	1·75	—	—

(1) Steels A-J were used for the drawing tests; steels I-III for the rolling experiments.
(2) Unintentional contamination from the scrap used.

steel C, and the high-silicon nickel-chromium-molybdenum steel H are shown as typical of the reaction of all the steels to sub-zero deformation. These data indicate that the tendency towards strengthening by working becomes greater as the temperature of working is lowered, and that the degree of increase in yield and tensile strength produced by a given amount of deformation is increased with fall in temperature, whereas the trend in elongation and reduction of area is in the reverse direction. As the temperature falls a smaller amount of deformation is required to produce a given increase in tensile strength, and with the most drastic cold-working done at the sub-zero temperatures the tensile values were 60–70 per cent. above those which would be obtained by a similar degree of deformation at room temperature.

With regard to the effect of low-temperature annealing after mechanical working the authors make the following observations: the effect of such treatment on steels which have been worked at room temperature is relatively slight, but lowering the temperature at which deformation is effected is associated with increasing response of the steels to subsequent heat-treatment. Tables and curves relating to steels A, B, D, and E indicate that, in accordance with expectation, the less stable low-nickel types (A and D) are appreciably hardened by deformation even at room temperature, and when deformed at −180°C. the difference in behaviour is even more clearly marked. A particularly large increase in mechanical properties, by sub-zero deformation, and by such treatment followed by heating at 400°C., was obtained in steel (H) low-nickel, high-silicon containing molybdenum. Results obtained on the chromium-manganese steel (J) were in keeping with the known work-hardening characteristics of high-manganese steels. Further curves deal with the influence of niobium-tantalum, and titanium, but no clear decision could be reached on this aspect of the subject.

A figure showing reduction in area after mechanical deformation at various temperatures reveals that although the determining factor is the tensile strength of the steels in the various conditions, temperature of deformation is not without influence.

Magnetic-saturation values, which had been determined on the steels in the initial condition, were measured also after the respective mechanical and thermal treatments, and the results were correlated with observations on structure and mechanical properties.

In addition to the tests relating to the influence of treatment at 400°C. on the mechanical properties of specimens previously cold-worked at the various temperatures used, the authors made a detailed survey of the effects of temperature of annealing and of duration of treatment, using temperatures and times more widely varied than those in the earlier tests. The steels used in these experiments were Nos I, II and III in the above table, heated under the varying conditions, after deformation at −180°C. Some of the observations made are noted below:

Treatment at 300°C. produced only very slow rate of increase in hardness, but the effect was definitely greater in steel II than in steel I. In both steels treatment at 400°C. produced maximum hardness, the value reached being much higher in II than in I: the increase was at first rapid, but later slowed down. Treatment at temperatures above 400°C. caused fall in hardness, which was at first gradual but subsequently became more rapid. In the chromium-manganese steel III, progressive hardening was still taking place after heating for 250 hours, the longest time used. (Attention is directed to certain differences between the effects observed in this series of tests and those on mechanical properties.) The heat-treatment investigations also included a study of the behaviour of the two-phase chromium-nickel-molybdenum steel D, with the aim of determining whether prior working at sub-zero temperature was conducive to formation of σ phase, and whether in steels so treated σ was formed in the 475°C. embrittlement range. With an annealing time of 24 hours formation of σ occurred on treatment at temperatures over the range 600°–900°: a maximum amount was formed at 700°C. Increasing the duration of the treatment widened, towards lower temperatures, the range in which σ was formed, but some of the results obtained on very long times of treatment at 500°C. were contradictory, indicating the need for further investigation. After 24 hours at 650°C. reversion of α to γ was complete and about 20 per cent. of σ was found. Decrease in temperature of treatment slowed down the reversion process. The observations made lead to the conclusion that the α solid solution resulting from cold-working favours formation of σ, and attention is also drawn to an embrittling effect found in the α constituent at lower temperatures of treatment. The cause of this embrittlement is not yet fully elucidated, but suggestions are made linking it with 475°C. embrittlement.

The final section of the paper describes exploratory tests to determine the influence of sub-zero mechanical deformation on corrosion-resistance of austenitic steels. These showed that the self-passivation limit in sulphuric acid is not affected by the γ to α transformation occurring on cold working, i.e., in passivating corrodents the field of useful application of the steels remains unaltered after the sub-zero treatment. In the active condition, however, the corrosion-resistance of steels which have been mechanically worked at sub-zero temperatures is adversely affected.

Drawing of Stainless-Steel Wire through Diamond Dies

W. F. G. KERLEY: 'Stainless Steel Wiredrawing through Dies.' *Wire Industry*, 1953, vol. 20, Nov., pp. 1095–6, 1099–1100, 1103, 1106, 1113.

This is an essentially practical article, designed to be of assistance to the foreman or departmental manager in solving his problems. As an introduction to the discussion of equipment and technique, the author traces the development of stainless-steel wiredrawing, and gives a description of the main features of a typical modern wiredrawing mill. The selection of the diamonds to be used for dies, their structure and properties, methods of mounting, and maintenance of diamond dies are then considered. The final section of

the article deals with the operations involved in wire-drawing of stainless steel, wear of dies, die lubrication, etc. The details of technique are based on the author's experience in a wiredrawing plant handling large quantities of stainless steel.

Specification for High-Alloy Steel Wire for Springs

BRIT. STANDARDS INSTN.: 'Rust-, Acid- and Heat-Resisting Steel Wire for Springs.' *B.S.2056:* 1953.

This specification comprises three parts: (1) general clauses relating to manufacture, test conditions, tolerances and circularity, (2) specific requirements covering composition and properties of (*a*) martensitic chromium steel wire to B.S. En 56A, 56B, 56C and 56D schedules, and (*b*) high-tensile martensitic chromium low-nickel steel wire to B.S. En 57; (3) specific requirements for austenitic chromium-nickel rust-, acid- and heat-resisting steel wire complying with B.S. En 58A–58H and 58J specifications. In all three groups of steel wire, tensile and wrapping test requirements are laid down, and for the austenitic wire a fracture and a dead-wire test are also specified. Material complying with specifications En 58B, 58C, 58F, 58G, 58H and 58J, when stabilized with titanium or niobium, is required to pass a bend test (after being subjected to the standard copper-sulphate treatment) for determination of susceptibility to intercrystalline corrosion.

Resistance of Nickel-Chromium Stainless Steels to Corrosion by Ammonium Salts

H. STÄGER: 'Study of the Corrosive Action of Ammonium Salts on Metals.' *Thesis presented at the Eidgenössische Technische Hochschule, Zürich,* (Promotions Arbeit No. 2157) 1952; 118 pp.

The experiments described were designed to investigate the corrosion of metallic materials by solutions of ammonium salts, with particular reference to the behaviour of corrosion-resisting steels under conditions of elevated temperature and pressure. Some comparative tests were made on brass, copper, zinc, cast iron, and steel.

In the stainless-steel series the materials selected for test were representative of commercial steels currently obtainable from firms in various countries; one martensitic, eleven austenitic, and two austenitic–ferritic types were used. Full details are given of experimental conditions and results.

In exposures at solution temperatures up to 100°C. iron and carbon-steel specimens were all heavily attacked by ammonium sulphate and ammonium chloride, but were more resistant to ammonium nitrate. The stainless steels were attacked to some extent by ammonium chloride, but proved completely resistant to ammonium nitrate and ammonium sulphate.

In tests on the corrosion-resisting steels at 150°–300°C. and at vapour pressures of about 100 atmospheres the behaviour varied very little among the different steels. In all cases they suffered the heaviest attack by ammonium chloride and ammonium sulphate: corrosion by ammonium bromide was less severe; with ammonium carbonate corrosion began only at a temperature of 200°C., and in ammonium nitrate no attack was observed below 250°C.

The investigation covered a comparison of the severity of total-immersion, half-immersion, alternating immersion, electrolytic and other forms of corrosion tests, and a study was made of the effect of oxygen concentration and of addition of other salts to the ammonium salt solutions.

Condenser-Tube Alloys: Recent Development and Current Practice

P. T. GILBERT: 'The Resistance to Failure of Condenser and Heat-Exchanger Tubes in Marine Service.' *Inst. Marine Engineers, Advance Copy,* Nov., 1953; 6 pp.

The author briefly refers to the prevalence, in earlier years, of condenser-tube corrosion which was one of the major problems of the marine engineer. Work carried out during the past three decades has, however, radically changed the position, and to-day there are commercially available condenser-tube materials which will withstand corrosion in all but the most adverse and abnormal conditions. While there is thus no longer a general condenser-tube problem, there remain certain individual conditions which adversely affect a very small percentage of the hundreds of thousands of miles of condenser tubing now in service. Since even one failure causes much inconvenience, it is important to reduce still further the incidence of failures, and to improve the performance of tubes in abnormal conditions where existing materials have not proved wholly adequate.

The paper opens with a review of the composition and properties of the materials now used for condenser tubes: aluminium brass, 70–30 cupro-nickel (preferably containing iron), copper-nickel alloys of the 95–5 and 90–10 types containing small additions of iron, and aluminium bronze. The corrosion-resisting characteristics of the respective materials are discussed, and it is pointed out that although in many conditions aluminium brass is entirely satisfactory, 70–30 cupro-nickel is to be preferred for severe conditions and is much used in the main condensers of warships and large merchant ships. The most recent development in this field has been the lower-nickel content copper-nickel alloys, in which the presence of controlled amounts of iron and manganese (earlier shown to enhance the corrosion-resistance of the higher-nickel alloys) ensures a degree of resistance which is adequate for many types of service.* In this introductory section of his paper the author also describes the different types of corrosion which may occur in condenser tubes: dezincification, impingement attack (or corrosion-erosion), and pitting: the conditions which give rise to the individual forms of attack are indicated.

In the second part of the paper a brief analysis is made of the sources of isolated cases of condenser-tube corrosion which have been investigated over the

* In connexion with the development of these alloys, see also abstract of paper by G. L. BAILEY, *Nickel Bulletin,* 1951, vol. 24 No. 8, p. 185.

period 1939–1952. Observations made during examination of the tubes have shown the following factors to be the most significant in relation to corrosion:

(1) The use of polluted cooling waters, particularly those containing hydrogen sulphide, sulphur, or organic sulphur compounds.
(2) Partial obstructions or deposits in tubes.
(3) Inefficient protector blocks.
(4) Sand erosion.
(5) Steam impingement.
(6) Mechanical factors connected with the installation or operation of the condensers.
(7) Operating practice.
(8) Use of incorrect or defective materials.

Each one of these factors is discussed in detail, particular attention being drawn to the deleterious effect of polluted waters, which are the most important single cause of deterioration of tubing. The significance of this condition is considered in relation to harbour and estuarine waters, and special attention is directed to the case of (1) power stations situated near estuaries or harbours, where the cooling water available has to be used irrespective of its purity, and (2) ships which are obliged to spend a considerable proportion of service life in harbour. The different types of corrosion which result from polluted waters are discussed and illustrated.

With regard to the effect of water velocity, it is pointed out that although the designed speed of water through the tubes of main condensers is at present of the order of 4–9 f.p.s., there is a tendency to increase them, and if pollution as well as higher speeds are to be encountered cupro-nickel of the 70–30 grade is to be preferred to aluminium brass. Conditions in which aluminium brass may satisfactorily be used, even at speeds considerably in excess of those now generally employed, are indicated.

In relatively clean sea water aluminium brass has a higher rate of heat transfer than cupro-nickel, but the influence of films of corrosion product, in reducing rates of heat transfer, is a factor which requires consideration.

Influence of Nickel Additions on the Corrosion-Resistance of Cast Copper-base Alloys

See abstract on p. 27.

Nickel Alloys in Magnetic Pumps for Handling Corrosives

F. D. ROSEN: 'Magnetic Pumps for Corrosive Gases and Liquids.' *Rev. Scientific Instruments*, 1953, vol. 24, Nov., pp. 1061–2.

The author describes the design of small, completely sealed, and magnetically operated pumps which have been constructed for circulation of corrosive gases. Correct selection of materials of construction is of primary importance, and in the models illustrated brass, Monel or stainless steel is used for the cylinder, and the piston is made from a ferromagnetic material, e.g., nickel.

The pumps may be operated either by an electromagnetic or permanent-magnetic field: in one design illustrated Alnico magnets are employed as the actuating medium. Pumps of the types described have been successfully used to handle gases such as uranium hexafluoride and hydrogen fluoride, at pressures up to 175 p.s.i.g. and 100°C.

Absorptiometric Determination of Cobalt in Nickel-Alloy Steels

See abstract on p. 28.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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